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(12) **EUROPEAN PATENT APPLICATION**

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(54) **Reflection type optical focusing apparatus.**

(57) A reflection-type optical focusing apparatus comprising an optical focusing system including at least two 4th-degree surface reflectors (30, 31) with their revolving symmetric axis formed by a line connecting the position of a point source (A1) and the point source focusing position (A2), said reflectors being used in combination so that the light emitted from a point source placed at the point source position is focused to form a virtual point source at the point source focusing position, and a 4th-degree surface reflector (32) with its cross-section, on a plane including the revolving symmetric axis, forming a part of an ellipse with its major axis having a certain inclination with respect to the revolving symmetric axis, said virtual point source being located at one focal point (A2) of the ellipse so that a light image in the shape of an arc band (12) is obtained.

FIG. 13

EP 0 066 295 A1
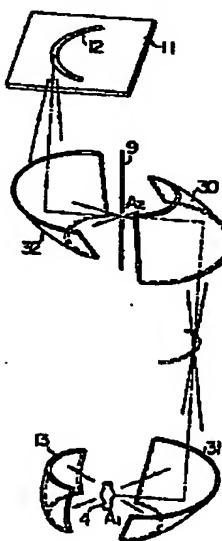
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REFLECTION TYPE OPTICAL FOCUSING APPARATUS

1   The present invention relates to a reflection-
type optical focusing apparatus which provides a light
source in the shape of an arc band used in a full-size
reflection-type exposing apparatus and the like.

5   The extra pressure mercury lamp and xenon-
mercury lamp used as a point source for exposing apparatus
in semiconductor fabrication are shaped as shown in Fig. 1,
where reference number 1 denotes a cathode electrode and
2 denotes an anode electrode. Lamps of this type emit
10 light by discharging, resulting in a somewhat planar
light source rather than an ideal point source. There-
fore, this light source is once focused at some position,
then reduced to an ideal point source using a pinhole
filter and the like.

15   Use of transmitting components such as lens
for focusing a point source is undesirable for some
wavelength, since it causes absoprtion and aberration.
On the other hand, use of reflectors for focusing a light
beam is free from these problems.

20   One of focusing methods using reflectors is
the use of an ellipsoidal reflector. In this case, the
highest light distribution intensity of the lamp appears
in the perpendicular direction with respect to the main
axis of the lamp, and in order to obtain the largest
25 effective energy at the focal point, the reflector has

1   to be shaped as shown in Fig. 2. In Fig. 2, reference

number 3 shows the conventional ellipsoidal reflector,

4 is a lamp, 5 is the position of the point source, and

6 is the point source focusing position. However, the

5   conventional ellipsoidal reflector 3, when provided with

a larger radiation angle around the main axis, does not

present a uniform light distribution around the focal

point.

    There is known an apparatus similar to the

10   present invention, as disclosed in Japanese Patent Laid-

open No. 54-123876 (corresponding to U.S. Patent No.

4,294,538) However, this apparatus causes the failure

df focusing in the meridian direction on the focal point

due to coma aberration, resulting in a large energy

15   loss when a pinhole filter is used.

    It is therefore an object of the present inven-

tion to solve the foregoing prior art deficiencies and

provde an optical focusing apparatus for obtaining a

light source in the shape of an arc band having a

20   uniform light distribution characteristic.

    The present invention is also characterized

in that there are provided reflectors each shaped in a

fourth-degree surface whose cross-section forms a

part of an ellipse with its major axis having a certain

25   inclination with respect to the revolving symmetric

axis, on one focal point of the ellipse is located the

effective point light source, thereby obtaining an arc

band light source to be used in an illuminating apparatus

1   for a full-size reflection-type exposing apparatus having
    a high resolution and short exposing time.

         The present invention is characterized in that
    there is provided the combination of at least two

5   reflectors each shaped in a fourth-degree surface having
    a revolving symmetric axis formed by a line connecting
    the position of the point source and the position of the
    point source focal point, so that the effective point
    light source as described in the above paragraph, is

10 obtained.

         According to the present invention, a light
    source of a short wave length (deep UV) ranging 200-300 nm
    can be obtained by use of an Xe-Hg lamp which provides
    a point source, and a high resolution is achieved.

15 Moreover, since optical transmitting components are
    not used, no optical loss occurs, and a light beam can be
    projected within a narrow band effectively.

         The present invention will be apparent from
    the following detailed description taken in conjunction

20 with the accompanying drawings, in which:

         Figure 1 shows an external view of the lamp used
    as a point source;

         Figure 2A is a perspective view showing the
    optical focusing system for a point source using the

25 conventional ellipsoidal reflector;

         Figure 2B is a side view of the optical system
    shown in Fig. 2A;

         Figure 3 is an illustration showing the present

1 invention;

Figure 4A is an illustation showing an embodiment of the present invention;

Figure 4B is a cross-sectional view of the
5 arrangement shown in Fig. 4A;

Figure 5A is an illustration showing the arrangement of another embodikent of the present invention;

Figure 5B is a cross-sectional view of the arrangement shown in Fig. 5A;

10 Figure 6A is an illustration showing the arrangement of another embodiment of the present invention;

Figure 6B is a cross-sectional view of the arrangement shown in Fig. 6A;

15 Figure 7A is an illustration showing the portions of dz, θ and dy shown in Figs. 6A and 6B;

Figure 7B is a graphical representation showing the focusing characteristics when the center of curvatxre is displaced from the revolving symmetric axis;

20 Figures 8A - 8E are ray tracing diagrams;

Figure 9 is an illustration showing still another embodiment of the present invention;

Figure 10 is a ray diagram for the light emitted from the finite light source used for the arc
25 band illumination, showing the affect of the present invention;

Figure 11A is an illumination ray diagram based on the system of the present invention;

1   Figures 11B and 11C are illumination ray

diagrams based on the conventional system;

         Figure 12 is an illustration showing the optical

system of the full-size reflection-type exposing apparatus

5 embodying the present invention;

         Figure 13 is an illustration exemplifying a

means for obtaining an effective point source according

to the present invention;

         Figure 14 is a ray tracing diagram for the

10 arc band illumination light produced by the combination

of three 4th-degree surfaces each having an ellipsoidal

cross-section as shown in Fig. 13;

         Figure 15 is an illustration explaining the

shape of the two concave mirrors used in the embodiment

15 of Fig. 13;

         Figure 16 is a ray tracing diagram for the arc

band illumination light produced by the combined illumi-

nation system made up of two 4th-degree surfaces each

having a circular cross-section shown in Fig. 13 and

20 a 4th-degree surface having an ellipsoidal cross-section

shown in Fig. 15; and

         Figure 17 is an illustration showing an embodi-

ment of the full-size reflection-type exposing apparatus

with the present invention applied thereto.

25   The present invention will now be described

in detail by way of illustrated embodiments.

         When focusing a point source in order to use

the lamp energy most effectively, the light beam

1 perpendicular to the lamp, where it has the highest
light distribution intensity, should be used. In addi-
tion, in order to obtain the uniform light distribution
around the focal point, the most suitable optical system

5 is the arrangement of 4th-degree surface reflectors
having a revolving symmetric axis formed by a line
connecting the point source position and the point source
focal position, with the hightest luminance portion of
the lamp being placed at the point source position.

10 Fourth-degree surface reflectors are classified by the
shape of the cross-section which is cut on the plane
including the revolving symmetric axis. For example,
assuming two 4th-degree surface reflectors each having
an ellipsoidal cross-section with one focal point located

15 out of the revolving symmetric axis and focal point
located at the point source position and the point source
focal point, respectively, a light beam originated from
point A1 reflects on surface S1 and focuses at C1 in
the shape of arc, then further reflects on surface S2

20 and focuses at point A2, as shown in Figs. 4A and 4B.

In another example, if reflectors have an
ellipsoidal and hyperbolic cross-sections each having
one focal point located out of the revolving symmetric
axis and another focal point located at the point source

25 position and the point source focal position, respectively,
a light beam originated from point A1 focuses at point
A2 as shown in Figs. 5A and 5B. Reflectors having circular
cross-sections generally cause the coma aberration.

1 Figure 7B shows intersections of the principal ray and

a ray having an inclination of θ with respect to the

principal ray measured by displacing the center of the

curvature of the circle from the revolving symmetric

5 axis as shown in Fig. 7A. In Fig. 7B, if dz is

equal to zero (as disclosed in Japanese Patent Laid-

open No. 54-123876 and corresponding U.S. Patent No.

4,294,538) or if dz is negative, θ-dy becomes a curve

and the coma aberration is not eliminated. On the other

10 hand, if dz increases in positive, θ-dy becomes a

straight line, and when two 4-th-degree surface reflectors

are combined with the focal point C being set temperarily

to the position of dy with θ=0 as shown in Figs. 6A

and 6B, the aberrations of both reflectors cancell

15 each other, resulting in a production of a clear image.

Thus the present invettion allows the production of a

clear point source image by using the light source

energy most effectively.

Next, the reflection-type optical focusing

20 system embodying the present invention will be described

with reference to Figs. 4A and 4B. Surfaces S1 and S2

define concave mirrors 20 and 21 on a 4th-degree

surface obtained by rotating the ellipsoidal cross-

sections expressed by equation (1) on a plane including

25 their revolving symmetric axis 7.

Ellipse: $\overline{A_i P_i} + \overline{P_i C} = \ell_i + h = \text{const} \ (i=1, 2) \ \ .. (1)$

1   Since points A1, C and A2 are the focal points

of these ellipses, the light source located at point A1

focuses to form an arc at point C, then it focuses to

form a point at point A2. Figure 8A shows the project-

5 ing ray at point A1, and Fig. 8B (ellipsoidal cross-

section plus ellipsoidal cross-section) shows the

incident ray at point A2. It can be seen clearly that

they have better characteristics as compared with

Fig. 8D (circular cross-section (with center on the axis)

10 plus circular cross-section (with center on the axis))

which results from the prior art arrangement disclosed in

Japaense Patent Laid-open No. 54-123876.

        Next, another embodiment of the reflection-

type optical focusing system according to the present

15 invention will be described with reference to Figs. 5A

and 5B. Surfaces S1 and S2 define concave mirrors 22

and 23 on 4th-degree surfaces obtained by rotating the

ellipsoidal and hyperbolic cross-sections expressed by

equations (2) and (3), respectively, on a plane including

20 their revolving symmetric axis·7.

Ellipse: $\overline{A_1P_1} + \overline{P_1C} = h + \ell_1 = \text{const}$ ...... (2)

Hyperbola: $\overline{A_2P_2} - \overline{P_2C} = h - \ell_2 = \text{const}$ ..... (3)

        Since points A1 and C are the focal points of

the ellipse and points A2 and C are the focal points

of the hyperbola, the light source at point A1 forms

1 an arc-shaped virtual image at point C, then the image

focuses at point A2 to form a point. The incident ray as

shown in Fig. 8C (ellipsoidal cross-section plus

hyperbolic cross-section) is obtained at point A2 for

5 the probjecting ray shown in Fig. 8A. It can be seen

clearly that they have better characteristics as compared

with Fig. 8D which results from the prior art arrangement

disclosed in the above-mentioned Japanese Patent Laid-

open No. 54-123876.

10   Next, still another embodiment of the reflec-

tion-type optical focusing system according to the present

invention will be described with reference to Figs. 6A

and 6B. Surfaces S1 and S2 define concave mirros 24 and

25 on 4th-degree surfaces obtained by rotating the

15 circular cross-sections expressed by equation (4) on

a plane including their revolving symmetric axis 7.

$$(\overline{A_i P_i} - h)^2 + (\overline{P_i C_i} - \ell_i)^2 = \gamma^2 = \text{cont} \ (i=1, \ 2) \ \ldots\ldots \ (4)$$

where $h \gg 0$.

      The light source located at point A1 forms an

arc at point C, then it focuses at point A2 to form

20 substantially a point. For example, in the case of the

prior art arrangement disclosed in the Patent Laid-open

No. 54-123876 with dimensions given as $h = \ell 1 - 0.0$ mm

and $\gamma = 150$ mm, the projecting ray as shown in Fig. 8A

results in an incident ray at point A2 as shown in Fig.

25 8D, whereas, according to the present invention, when

1   the centers of the circles are located out of the

revolving symmetric axis with the dimensions being given,

for example, as $l1 = l2 = 040.6$ mm, $h = 75.1$ mm and

$\gamma = 250.0$ mm, the incident ray is improved as shown in

5   Fig. 8E (circular cross-section (with center out of the

axis) plus circular cross-section (with center out of

the axis)).

The foregoing embodiments allow the formation

of a clear image for realizing an ideal point source

10   (effective point source) by gathering the lamp energy

efficiently.

The following will describe the full-size

reflection-type exposing apparatus using the effective

point source.

15   First, formation of an effective point source

into an arc band by use of a 4th-degree surface reflector

will be described. Figure 9 illustrates the optical

system of the 4th-degree surface reflector. A line

passing through the center of an arc band 12 and per-

20   pendicular to a surface S4 of the arc band is defined

as a revolving symmetric axis l, and an effective point

source A2 is positioned on the axis. A 4th-degree surface

is formed such that its profile σ (curve) obtained by

cutting the surface on a plane S3 including the revolving

25   symmetric axis forms an ellipse having one focal point

located at the point source and another focal point

at the intersection of the center line D of the arc

band and the plane S3. In such arrangement, it is

1 clear due to the ellipsoidal profile σ that a ray

emitted from the effective point source A2 and propagated

on the plane S3 will reflect on the profile σ and will

focus on the intersection I of the center line D and

5 the plane S3. More generally, a ray emitted from point

A2 and reflected on the surface Σ of the 4th-degree

surface reflector will focus on arc D due to the fact

that the surface Σ has its revolving symmetric axis on

the line ℓ and the center line D of the arc band has its

10 revolving symmetric axis also on the line ℓ. Although

the effective point source A2 provides the luminous

distribution extending around the arc band D due to a

finite area of the light source, it illuminates the

inside of the narrow arc band at a high light utilization

15 efficiency owing to the high focusing characteristic at

the point I.

Figure 9 shows the basic arrangement of the

present invention, in which an effective point source 6

is located at point A2 (focal point of ellipse σ), and

20 the 4th-degree surface is cut to form a reflector 32

so that a ray projected to the center of the reflection

surface Σ reflects in substantially perpendicular to the

incident path. A diverging ray from the point source 6

reflects on the surface Σ and focuses on the arc slit 12.

25 Figure 10 is a ray tracing diagram for a ray emitted

from the center, i.e., the focal point A2, of the diverg-

ing effective point source 6 (indicated by the solid

line) and a ray emitted from a point which is offset

1 by ± 0.5 mm from the point A2 (indicated by the dot and

dash line).

In contrast to the projecting ray shown in

Fig. 10, Fig. 11A is a ray diagram on a plane perpendi-

5 cular to the arc band when the 4th-degree surface having

a ellipsoidal cross-section on the plane S3 is used

according to the present invention. The solid line,

dashed line, and dot and dash line in Fig. 10 corres-

-pond to those in Fig. 11. Figures 11B and 11C are ray

10 diagrams of the conventional reflection-type optical

system, Fig. 11B using a spherical mirror, Fig. 11C using

the combination of three spherical mirrors. Figure 11A

according to the present invention shows less failure

of focusing as comapred with any conventional case,

15 and apparently a narrow area is illuminated effectively.

The following will describe the shape of the

4th-degree surface mirror used in the embodiment of

Fig. 9. If the arc band has a radius of curvature of

r' (equal to A2 P), and if,

$$IP = mr'$$

20 then the 4th-degree surface Σ, with the origin located at

point A2, is expressed as follows.

$$\{(2m+1)z^2+m(m+2)(x^2+y^2)+2m^2r'z-m^2r'^2\}^2$$
$$= 4m^2(r'-z)^2(x^2+y^2) \quad \dots\dots\dots\dots\dots\dots\dots\dots \quad (5)$$

Figure 12 shows the full-size reflection-type

1   exposing apparatxs incorporating the foregoing embodi-

ment of the present invention. A ray emitted from the

effective point source 6 reflects on the 4th-degree

surface 32 expressed by equation (5), and an arc slit

5   illumination 12 is obtained on the mask 11. The ray

transmitting the mask 11 reflects on the concave

mirror 33 and convex mirror 34 twice and once, respec-

tively, and projects an image pattern 36 of the arc

slit on the wafer 35. Accordingly, by scanning the wafer

10   35 and the mask 11 at the same speed in respective direc-

tions shown by the arrows, the pattern of the mask 11

can be exposed on the entire surface of the wafer 35.

      Figure 13 shows an embodiment of the full-size

reflection-type exposing apparatus according to the

15   present invention, in which reference number 4 denotes a

point source employing a Xe-Hg lamp, and 30 and 31 are

concave mirrors for converging the light emitted from

the point source. In this embodiment, the following

concave mirrors are used for the mirrors 20 and 21

20   shown in Fig. 4.

(1)   The concave mirror 30 is derived from the

4th-degree surface mirror 20 defined by equation (5)

with m = m1.

(2)   The concave mirror 31 is derived from the 4th-

25   degree surface mirror 21 defined by the equation (5)

with m = m2.

      The spatial relationship between the concave

mirrors 20 and 21 is that they have a common revolving

1   symmetric axis and their focal points, which are the

intersections of a plane including the revolving symmetric

axis and the reflection surfaces of both concave mirrors

and are located out of the revolving symmetric axis,

5   are located substantially at the same point. In this

arrangement, the 4th-degree surface mirrors 20 and 21

provide an effective point source at point 6. Using

this effective point source as a new point source, an

arc band illumination 12 can be obtained by use of a

10   4th-degree surface 2 in the same way as in the embodi-

ment shown in Fig. 9. Figure 14 is a ray digram for

the illumination system fromed by the combination of

three 4th-degree surfaces each having an ellipsoidal

cross-section, showing the characteristics of a ray

15   emitted from the center Al of the light source 4 in the

arrangement of Fig. 13 (indicated by the solid line) and

rays emitted from the points which are offset by ± 0.5 mm

from the center (indicated by the dashed line, and dot

and dash line) on the mask 11 shown in Fig. 13. The

20   figure shows that a better arc band illumination can be

obtained as compared with the cases of Figs. 11B and

11C.

     Next, another embodiment will be described in

connection with Fig. 13. In this embodiment, concave

25   mirrors 30 and 31 are of the type shown by 24 and 25 in

Fig. 6.

    (3) Concave mirror 31: Identical to mirror 25

     As shown in Fig. 15, the concave mirror 25 has

1 a revolving symmetric axis ℓ21 passing through a light

source 4, and the intersection of a plane S21 (x/z plane)

including the symmetric axis and the concave mirror 25

defines a circle with its center located out of the ray

5 axis ℓ21. Whet the light source is located on the

origin, the center of the circle is located at (x_o, z_o),

and the surface Σ of the concave mirror 25 satisfies the

following 4th-degree equation.

$$\{r^2_c-(z-z_o)^2-x^2-y^2-x_o^2\}^2 - 4x_o^2(x^2+y^2) = 0 \quad \ldots \quad (6)$$

(4) Concave mirror 30: Identical to mirror 24

10 The concave mirror 30 is identical to that shown

in Fig. 15 and has the same revolving symmetric axis.

The location of point 0" corresponding to point 0' of

the mirror 25 is defined, for example, as 0' - 0" = 81 mm

when rc = 250 mm, xo - 75 mm and zo - 177 mm.

15 The ray diagram on the mask surface 4 according

to this embodimett is shown in Fig. 16 (the illumination

ray by the illumination system formed by the combination

of two 4th-degree surface each having a circular cross-

section and a 4th-degree surface having an ellipsoidal

20 cross-section). The figure shows that the similar or

better arc band illumination 9s obtained as compared

with the case of Fig. 14. It will be appreciated that

light emitted from the point source 4 and traveling in

directions opposite to the concave mirror 31 can be used

25 effectively by provision of a spherical mirror 13 having

1   its center of curvature located at the point source.

Next, still another embodiment will be described
in connection with Fig. 13 and Fig. 5. The light
emitted from the lamp 4, used as a point source, is
5   converged to form an arc band shown by the dashed line
in Fig. 5 using a 4th-degree surface mirror having its
revolving symmetric axis formed by the line 7 shown in
the embodiment of Fig. 1 and also having an ellipsoidal
cross-section. If a 4th-degree concave mirror 22,
10 having a hyperbolic cross-section with its focal points
located on the arc and having the revolving symmetric
axis 7, is inserted between the ellipsoidal concave
mirror and the arc, the light emitted from the light
source 4 will converges to form an effective point
15 source at point 6.

In converging the point source originated from
the lamp to form an effective point source by using the
foregoing reflection-type optical system, if a pinhole
filter 9 having a circular opening (pinhole) is placed
20 at the focal point as shown in Fig. 13, the area of the
light source can be made smaller so that it further
approaches the real point source. The optical systems
as shown in Figs. 3, 4A and 5A can be replaced by a
simple and ideal point light source.

25 The full-size reflection-type exposing apparatus
using the reflection-type optical focusing apparatus
according to the present invention will be described
with reference to Fig. 17. Reference number 40 denotes

1   the reflection-type optical focusing apparatus shown in

     Fig. 13, and it is mounted on a flat plate 41. In

     order to take a longer distance between the concave

     mirrors 30 and 31, the apparatus is provided with flat

5   reflectors 36 and 37. A moving tray 42 is supported

     slidably by a bearing 47 on the flat plate 41. A means

     43 for holding a mask 11 is fixed on the moving tray 42.

     An X-Y-θ table 44 for mounting a wafer 35 is fixed on

     the moving tray 42. Reference number 45 denotes a

10   driving power source for moving the tray 42, and its

     output is connected through a steal belt or the like 46

     to the moving tray 42. A full-size reflection-type

     optical system 50 includes reflectors 51, 52 and 53,

     a concave spherical mirror 33 and a convex spherical

15   mirror 34, and it is mounted on a support 48 provided on

     the flat plate 41. Reference number 54 denotes an

     optical detection system for registering the alignment

     pattern on the wafer 11 to the alignment pattern on the

     mask 35. In the foregoing arrangement, the wafer 35

20   and the mask 11 are aligned by using the optical

     detection system 54, thereafter circuit patterns projected

     in the form of an arc band on the mask 35 by the reflection-

     type focusing apparatus 40 is transferred onto the wafer

     11 by moving the tray 42 in a certain direction.

25   The reflection-type optical focusing apparatus

     according to the present invention can be used not only

     for the above-mentioned full-size reflection-type exposing

     apparatus, but more extensively for exposing apparatus

1 of the type where exposure is carried out by scanning

the mask and wafer. For example, application of the

apparatus to a contact exposing apparatus and proximity

exposing apparatus using ultraviolet rays or deep

5 ultraviolet rays provides the following advanced charac-

teristics as compared with the conventional system. It

has been impossible to obtain a uniform and parallel

illumination ray from a point source solely by using

a reflection-type optical system, and therefore, fly-eye

10 lens made of transmitting quartz and quartz lens have

been used. However, such optical system using expensive

quartz components has not provided a satisfactory uniform

and parallel illumination ray. The illumination

apparatus for exposing apparatus according to the present

15 invention achieves a constant luminous level in any

place on the arc band and also a satisfactory parallel

ray. Moreover, the illumination apparatus for exposing

apparatus according to the present invention does not

need transmitting optical components (by choosing the

20 value of m in the range from 2 to 5), thereby allowing

the low-cost design. This advantage is further stressed

for the light having a shorter wave length for which

transmitting optical components cannot be used.

According to the present invention, as described

25 above by way of embodiment, the light emitted from a

point source or a light source having a small lighting

area similar to the point source can be projected to a

narrow area in the form of an arc band clearly, whereby

1 only the narrow arc band pattern can be exposed onto the
wafer. Therefore, only the satisfactory narrow arc band
area produced by the optical projection system made u!
basically of concave and convex mirrors is used to

5 expose the wafer by scannign the mask and wafer at a
high speed, and a high resolution pattern can be trans-
ferred to the wafer at a high speed.

Thus the present invention is very effective
for improving the quality of focusing and economical

10 condition at the same time.

1   WHAT IS CLAIMED IS:

1.   A reflection-type optical focusing apparatus

comprising a 4th-degree surface reflector (32) with its

cross-section, on a plane including a revolving symmetric

5   axis, forming a part of an ellipse with its major axis

having a certain inclination with respect to said

revolving symmetric axis, a virtual point source being

located at one focal point (A2) of said ellipse so that

a light image in the shape of an arc band (12) is

10 produced.

2.   A reflection-type optical focusing apparatus

according to Claim 1, wherein at least two 4th-degree

surface refrectors (20, 21; 22, 23; 24, 25) having

their revolving symmetric axis formed by a line (7)

15 connecting the position of a point source (A1) and the

point source focusing position (A2), said refrectors

being used in combination such that the light emitted

from a point source located at said point source posi-

tion is focused to form a point source at said point

20 source focusing position.

3.   A reflection-type optical focusing apparatus

according to claim 2, wherein said two 4th-degree

surface reflectors have their conjugate points located

at said point source position (A1) and said point source

25 focusing position (A2), said reflectors comprising a

first 4th-degree surface reflector (21) with its cross-

section, r a plane including said revolving symmetric

axis, forming a part of an ellipse having its focal

points located at one (A1) of said conjugate points and
a point (C) out of said revolving symmetric axis, and a
second 4th-degree surface reflector (20) with its
cross-section, on a plane including said revolving

5 symmetric axis, forming a part of an ellipse having its
focal points located at a point (C) out of said revolving
symmetric axis and another one (A2) of said conjugate
points.

4.   A reflection-type optical focusing apparatus

10 according to claim 2, wherein said two 4th-degree surface
reflectors have their conjugate points located at said
point source position (A1) and said point source focusing
position (A2), said reflectors comprising a first 4th-
degree surface reflector (23) with its cross-section, on

15 a plane including said revolving symmetric axis, forming
a part of an ellipse having its focal points located at
one (A1) of said conjugate point and a point (C) out of
said revolving symmetric axis, and a second 4th-degree
surface reflector (22) with its cross-section, on a

20 plane including said revolving symmetric axis, forming
a part of a hyperbola having its focal points located at
a position (C) out of said revolving symmetric axis and
another one (A2) of said conjugate points.

5.   A reflection-type optical focusing apparatus

25 according to claim 2, wherein said two 4th-degree
surface reflectors (24, 25) have their conjugate points
located at said point source position (A1) and said
point source focusing position (A2), each of said

reflectors having its cross-section, on a plane
including said revolving symmetric axis, forming a part
of a circle with its center of curvature located out of
said revolving symmetric axis.

5   6.   A reflection-type optical focusing apparatus
according to claim 2, wherein a small circular aperture
is provided at the position (A2) of said virtual point
source.

        7.   A reflector-type optical focusing apparatus
10 for use in an exposing apparatus which focuses a light
image illuminated on a mask in the shape of an arc band·
onto a wafer (35) by means of an optical focusing system,
said focusing apparatus comprising an optical focusing
system including at least two 4th-degree surface reflec-
15 tors (30, 31) with their revolving symmetric axis
formed by a line connecting the position of a point
source (A1) and the point source focusing position (A2),
srid reflectors being used in combination so that the
light emitted from a point source placed at said point
20 source position is focused to form a virtual point
source at said point source focusing position, and a
4th-degree surface reflector (32) with its cross-section,
on a plane including said revolving symmetric axis,
forming a part of an ellipse with its major axis having
25 a certain inclination with respect to said revolving
symmetric axis, said virtual point source being located
at one focal point (A2) of said ellipse so that said
light image in the shape of an arc band (12) is obtained.

- 4 -

8.   A reflection-type optical focusing apparatus
for use in an exposing apparatus according to claim 7,
wherein said optical focusing system in said exposing
apparatus comprises a full-size reflection-type optical
5 system including a concave spherical mirror (33) and a
convex spherical mirror (34).
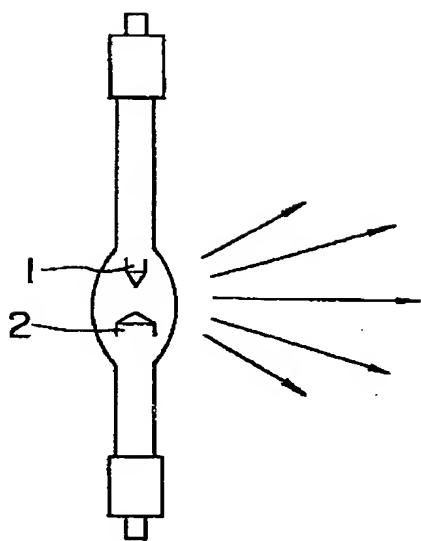
FIG. 1

FIG. 3
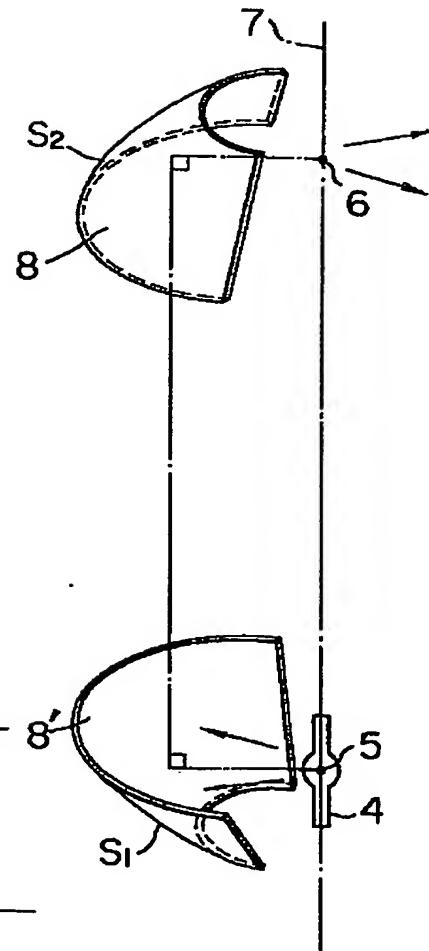
FIG. 2A
PRIOR ART
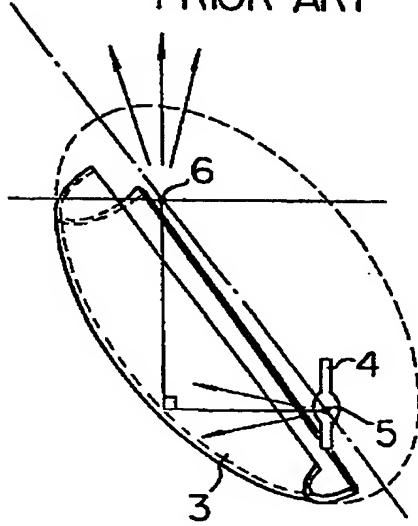
FIG. 2B
PRIOR ART
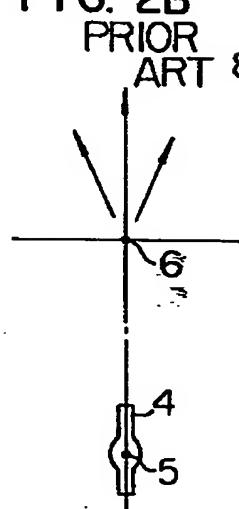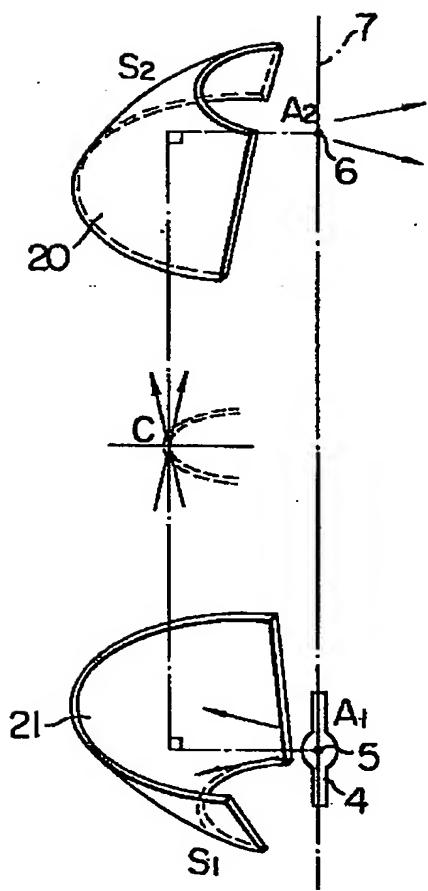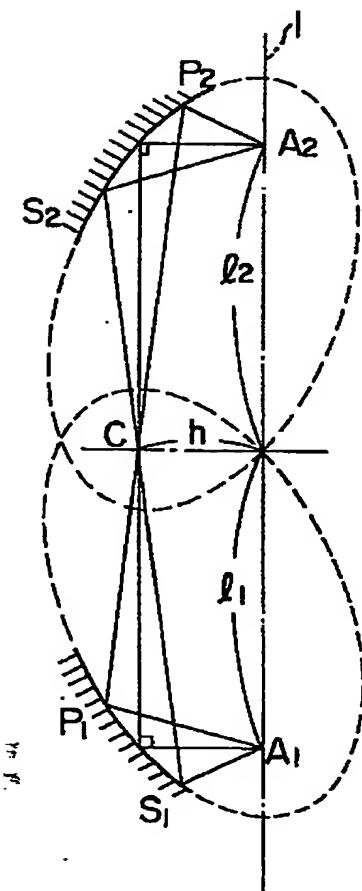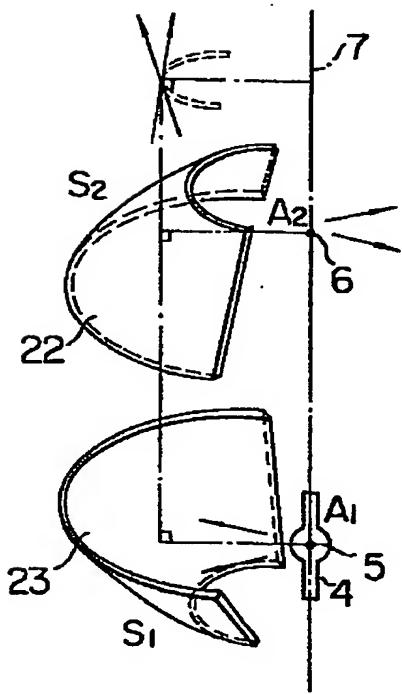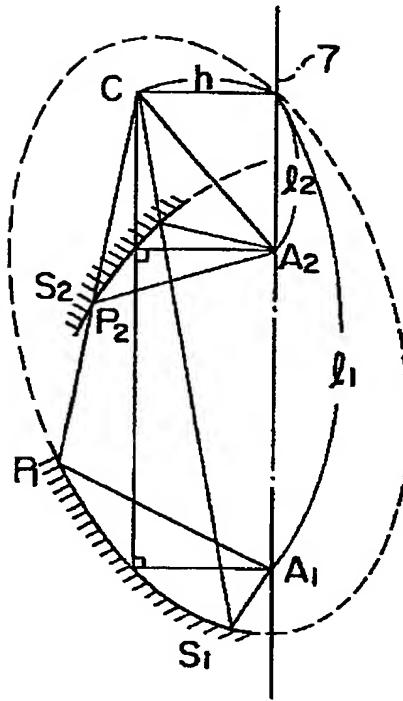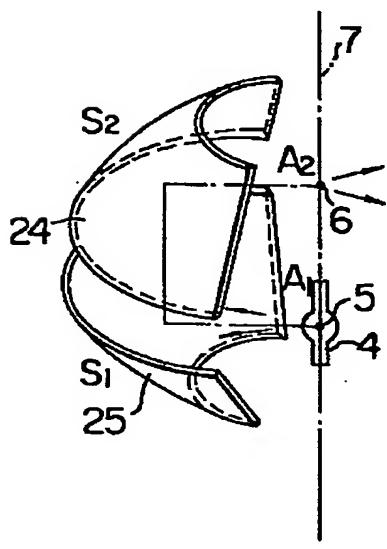
FIG. 4A

FIG. 4B

F I G. 5A

FIG. 5B

FIG. 6A

F I G. 6B
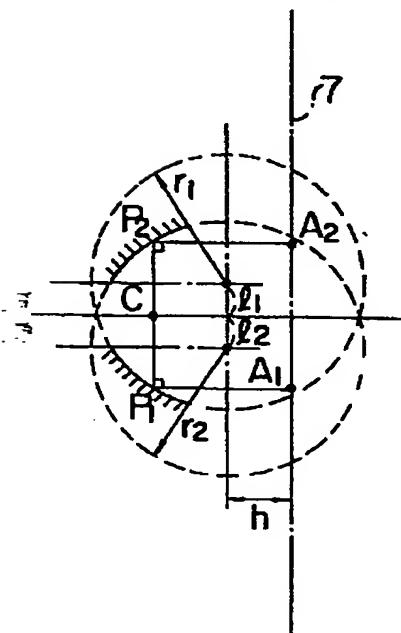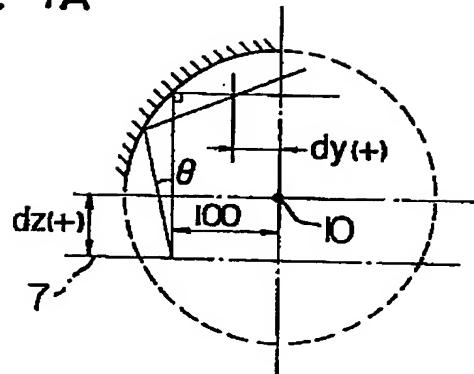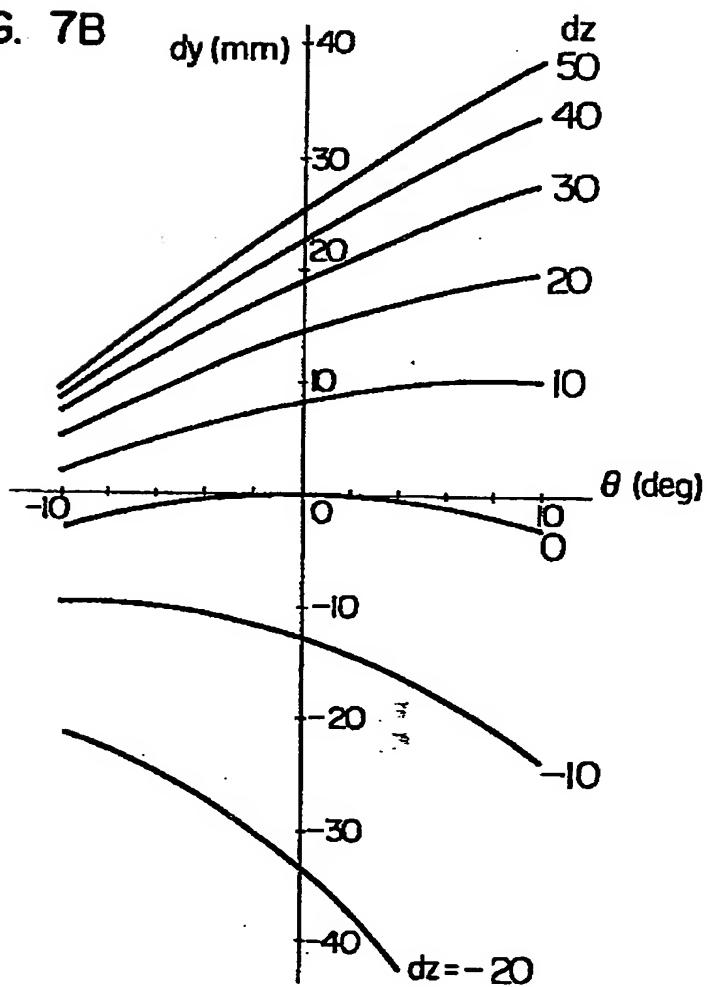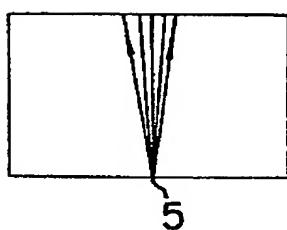
FIG. 7A

dy(+)

θ

dz(+)

100

10

7

FIG. 7B

dy (mm)

40

dz

50

40

30

20

10

30

20

10

0

θ (deg)

-10

0

10

-10

-20

-10

-30

-40

dz = -20

FIG. 8A

5

|——| 1 mm

FIG. 8B

6

FIG. 8D

6

FIG. 8C

6

FIG. 8E

6
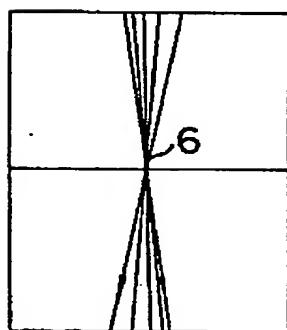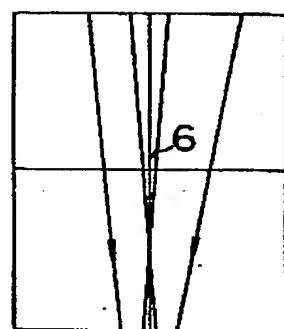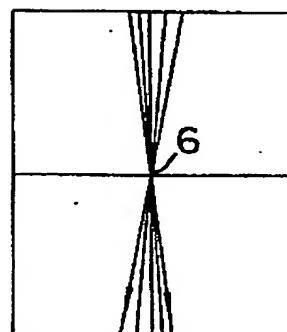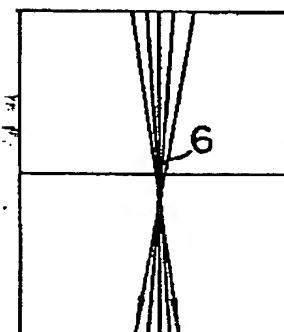
FIG. 9
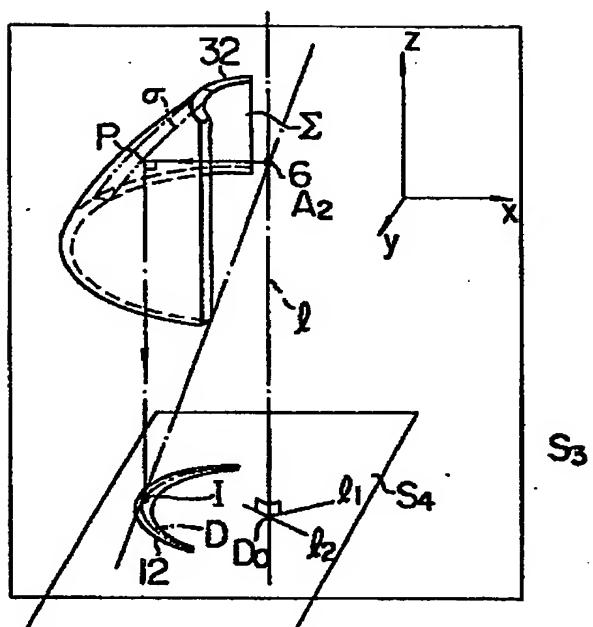
FIG. 10
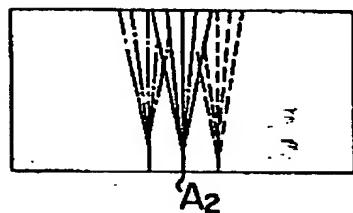
0   1   2mm

FIG. IIC

RADIAL
DIRECTION
OF ARC
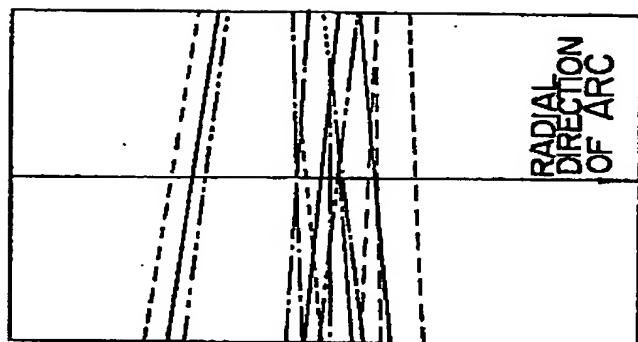
0 1 2mm

FIG. IIB

0 1 2mm

FIG. IIA

RADIAL
DIRECTION
OF ARC

0 1 2mm

FIG. 12

FIG. 13

FIG. 14

RADIAL
DIRECTION
OF ARC

4'

O   I   2mm
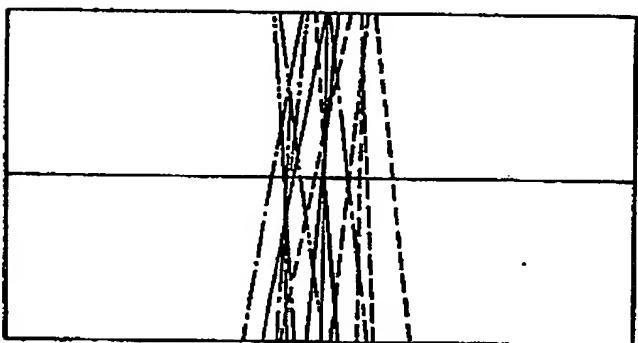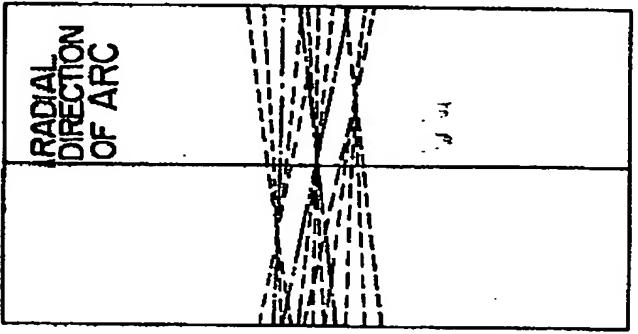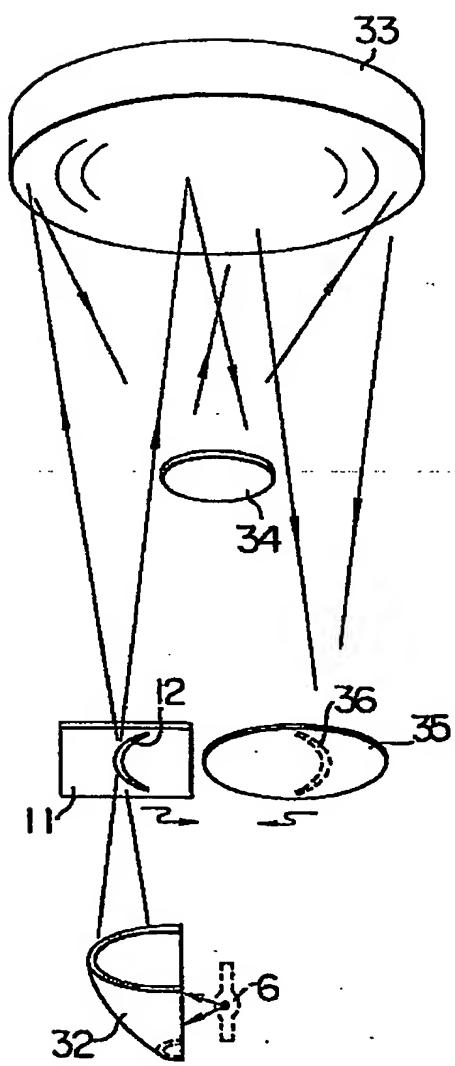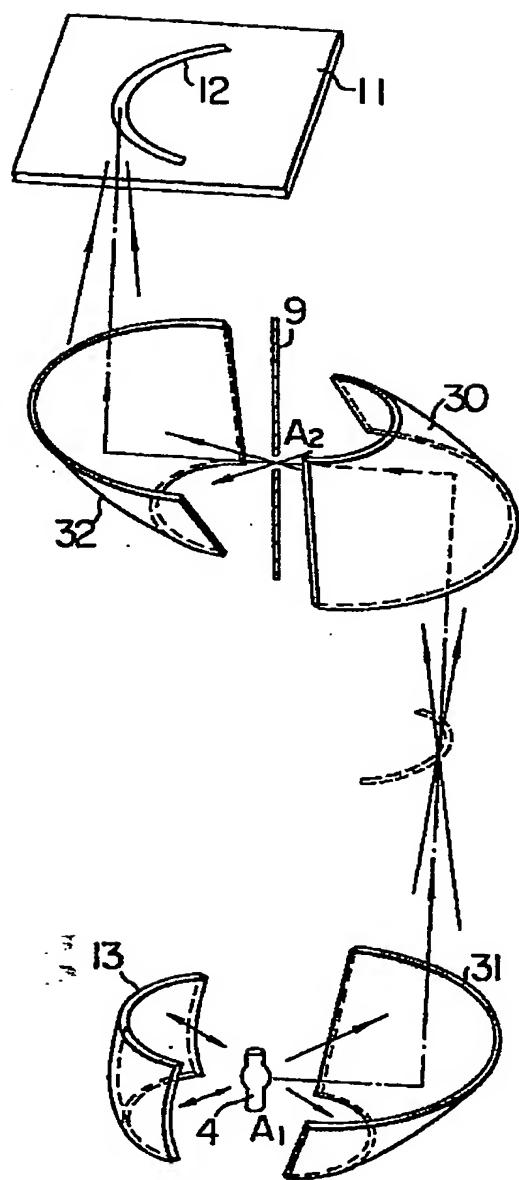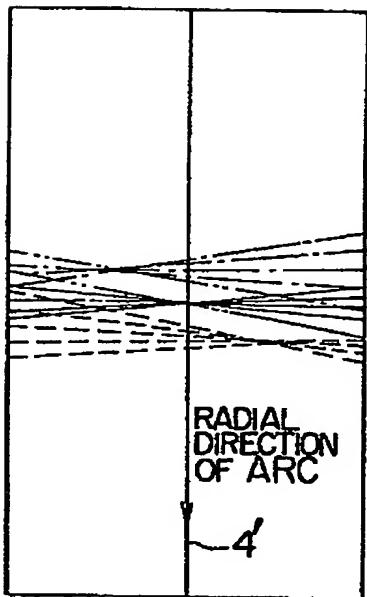
FIG. 16
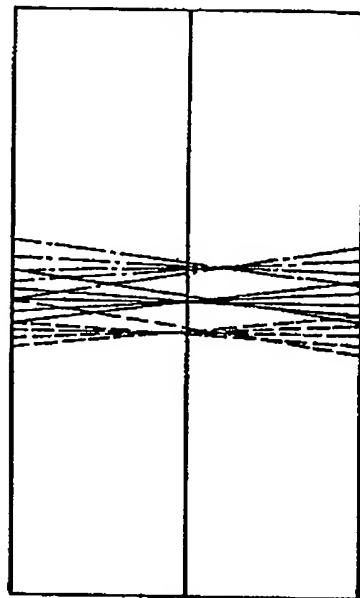
SPHERE/SPHERE
/ELLIPSE   THE 3RD
(MODIFICATION REFLECTION
SYSTEM)

O   I   2mm

FIG. 15
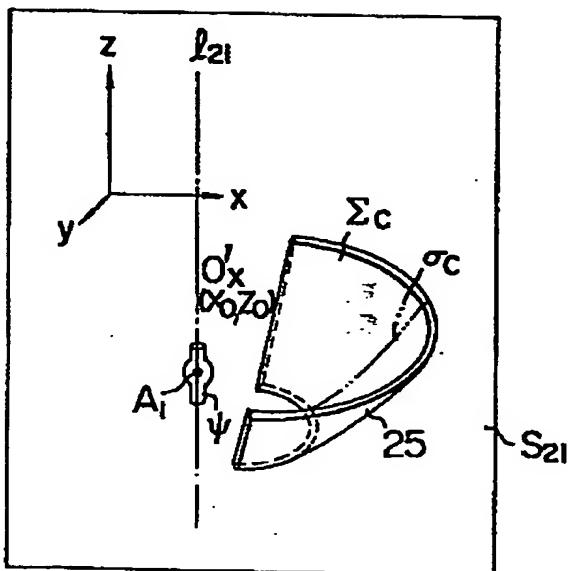
F I G. 17
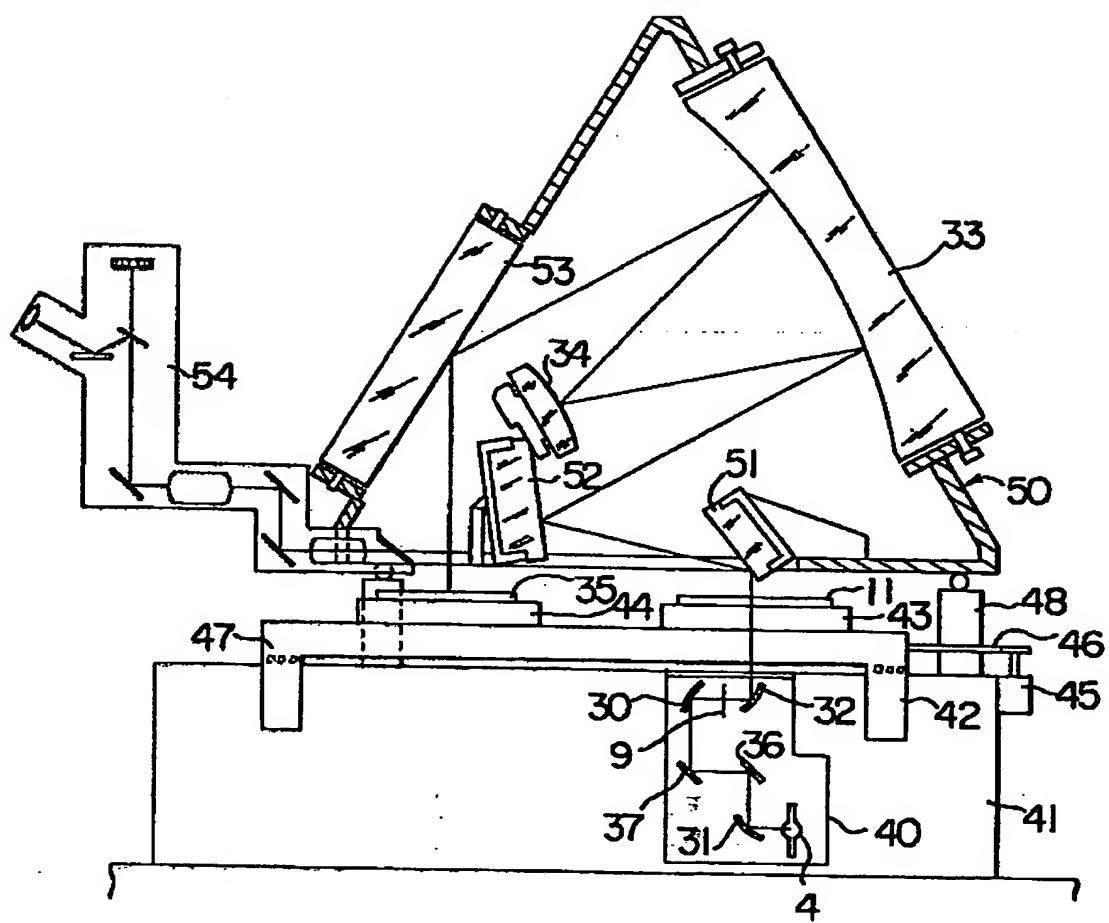
Eur pean Pat nt
Office

EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	DE-A-2 910 280 (CANON) *Page 5, lines 21-35; page 8, lines 6-16; claims 1-3; figures 2,6* & US - A - 4 294 538 (Cat. D,P,Y)	1-5,7, 8	G 02 B 17/00 G 02 B 19/00

Y	EP-A-0 022 346 (EALING INFRA-RED) *Page 3, lines 1-13; figure 3; claims 1-6*	1-5	

A	DE-A-2 505 257 (RICOH CO.) *Abstract; figures 7,8*	1,7	

A	US-A-3 763 348 (COSTELLO) *Abstract; figure 4*	1,7	**TECHNICAL FIELDS SEARCHED (Int. Cl. ³)**

A	US-A-3 963 353 (HEMSTREET) *Column 2, lines 3-5,22-28; figure 1*	1,7	G 02 B G 03 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-07-1982	SEIFERT H.U.